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Analysis of Irrigation Potential in the Southeast: Florida, A Special Report

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ABSTRACT

The doubling of population in Florida between 1960-80 brought about increasing demands for water by agricultural and urban-industrial activities. Irrigated acreage remained highly concentrated in the central counties around Lake Okeechobee, where climatic factors are especially conducive to the production of specialty crops such as citrus, vegetables, tropical fruits, and sugarcane. Prolonged drought during the early 1960's stimulated significant growth in the region's irrigated acreage. In recent years, other U.S. regions and Mexico have provided Florida with intense competition in the market for specialty crops. Florida has 1.2 million acres of unirrigated cropland and another 1.5 million acres of pastureland in soil classes I, II, and III, which represent potential area for irrigation development.

Keywords: Irrigation growth, drought, freeze damage, consumptive water use, irrigation cost, National Resource Inventory.

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PREFACE

Irrigated land use in humid regions has important implications for national water development policy as water resources in the irrigated arid West are becoming increasingly limited. Florida provides an interesting geographical setting for studying the various demands on water resources in the East. Florida, with its diverse economy, is experiencing intense competition for water from the growing needs of municipalities and industries.

An in-depth analysis of irrigation in Florida emphasized irrigation development for specialty crops that have large national markets. Florida accounts for over 20 percent of the total irrigated acreage of the 31 humid Eastern States. Because Florida's present and future contributions to the production of citrus, vegetables, sugarcane, and other crops are large, the State was given first priority for the study of Southeast irrigation potentials. This study generates new information applicable to the broader southeastern regional study.

Florida's agriculture is increasingly influenced by improved water management practices, including irrigation, drainage, and flood control techniques. Ground water is a major source of the water used for irrigation in Florida, and the need to protect aquifers from heavy overdraft has increased. Frequent droughts which occur in some areas in the humid East aggravate water shortages. The area around Lake Okeechobee in Florida ia a good geographical example of intermittent regional water scarcity during drought periods. This area requires specially designed methods to conserve or increase water supplies, such as replenishing of aquifers when streams approach flood stages. Adopting water conservation techniques, such as capital-intensive drip irrigation, for reducing water use in agriculture is another approach for solving water shortages. Application of these techniques will vary according to physical variables, economic considerations, and regions.

Pollution caused by fertilizers running off of agricultural lands from heavy rains in some humid areas has increased the complexity of the water resource management task and requires stronger efforts to achieve comprehensive resource management.

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SUMMARY AND CONCLUSIONS

Population growth and irrigation expansion have been important factors affecting water use in Florida. The doubling of population in Florida between 1960-80 brought about increasing demands for municipal and industrial water. This has also been accompanied by an expansion of irrigated cropland.

During 1954-82, total irrigated land increased from 427,000 acres to about 2 million acres by 1978, and then declined by 1982 to 1.6 million acres. A recent decline in irrigation acreage appears to be very temporary and is attributed to a decline in pastureland irrigation, as precipitation was ample in 1982 for pasture plants.

Irrigated cropland remained highly concentrated in the central and southern counties, with Palm Beach County alone accounting for 19 percent of irrigated acreage in 1982. Most irrigated areas showed a downward trend between 1978 and 1982; however, Indian River County experienced 12-percent growth during the same 4-year period.

Urban expansion has occurred in eight counties, and urbanized areas in the State increased from 881,000 acres in 1960 to approximately 2.6 million acres in 1980. Among the eight urban counties, harvested cropland declined in five counties, increased in two counties, and showed no change in one county.

The most important climatic factors having a direct relationship to irrigation development are temperature and the incidence of drought. Temperature for citrus production should remain above 26°F in January. Subtropical fruits, including mangoes, usually require temperatures which do not reach the freezing point. Sugarcane grows all year long and flourishes under warm climatic conditions. All of these crops require irrigation water for optimal growth. The drought incidents of 1961-64 were important in triggering and sustaining growth of irrigated cropland in the early 1960's, when this region experienced its sharpest increase in irrigated cropland.

Among the various crops grown in Florida, sugarcane, a perennial crop with 48.5 inches of consumptive use, has the highest annual use of water. Citrus, another perennial crop, has an annual consumptive use of 44.6 inches of water, whereas rice, a staple crop grown in summer months, requires 8.43 inches of consumptive use of water for July.

Annual irrigation water use in Florida was 3.4 million acre-feet in 1980, of which 1.7 million acre-feet was consumptive use. For the entire State, ground water sources, chiefly the Floridan and Biscayne aquifers, supplied 1.8 million acre-feet of water while surface sources accounted for 1.6 million acre-feet. On the average, 1.7 acre-feet of water per acre was applied in the State, with an average consumptive use of only 0.85 acre-feet per acre.

Most of the prime farmland is located in the panhandle counties, where fertile soils are mainly in the Dothan-Orangeburg-Fauquay association. These soils represent areas of potential irrigation development. According to the 1982 National Resources Inventory (NRI) data, there are 2.52 million acres of class I, II, and III land in cropland in Florida. In the same three categories of land classification, there are 1.75 million acres of pastureland. Their combined acreage of 4.27 million acres can be irrigated, out of which 1.58 million acres are already irrigated. This means there are 2.69 million acres remaining which can be brought under irrigation. Neither land nor water is a limiting factor

for irrigation development. Trickle irrigation systems with spray jets have been adopted increasingly in citrus production because these systems provide advantages of both lower initial and operating costs as compared with permanent sprinklers and traveling gun systems.

Thus, the development of irrigated cropland will be influenced chiefly by the growth of markets, and the sales competition from other countries and U.S. regions, especially California and southern Texas, where citrus and vegetable production is also concentrated. Finally, certain tropical South American countries including Brazil have expanded their U.S. markets for fruits and vegetable production, as low-paid labor allows them to produce at lower costs that are very competitive with those in the United States.

Analysis of Irrigation Potential in the Southeast: Florida, A Special Report

Rajinder Singh Bajwa

INTRODUCTION

Supplemental irrigation is an important production practice for the high-valued crops grown in Florida where the subtropical climate favors production of vegetables, citrus, sugarcane, and tropical fruits. Census of Agriculture reports for 1982 indicate important changes in Florida's irrigation. Irrigated acreage declined between 1978 and 1982 in Florida as well as in 14 Western States because of a combination of factors such as rising energy prices, falling commodity prices, increasing nonagricultural competition for water, and declining ground water levels. The decline in irrigated acreage in Florida is also partly attributed to favorable weather conditions prevailing in 1982 which provided sufficient moisture for pasture.

But, in the same 4-year period during which irrigated acreage declined in Florida, irrigated cropland increased in the humid East, with major increases in areas where underground and surface water supplies were plentiful, particularly in Georgia and the Great Lakes States. With rising commodity prices, the increase in irrigated cropland will probably continue in some humid areas and be especially pronounced in the Southeast and Great Lakes farm production regions.

Population growth and irrigation expansion have been important factors affecting water use in Florida. The doubling of Florida's population between 1960 and 1980 brought about increasing demands for municipal and industrial water uses. An expanding agriculture required increasing quantities of water for irrigation. The combined effect of these changes resulted in a lowering of the ground water level of 150 feet or more in some areas of the Floridan aquifer. Increased urban and agricultural water uses have also lowered the water level of many lakes in central Florida. For example, more than 90 lakes in central Florida required augmentation with water from wells during 1982 (3, 30, 32). 1/

Numerous climatic, resource, and economic factors influence the use of supplemental irrigation. The influence of major factors such as timing and intensity of drought occurrence, climate, soils, availability of irrigable land, water supplies, profitability of irrigation, and investment requirements are important in understanding irrigation development. There is a need to identify and assess the extent to which combinations of resources and climate favor irrigation expansion. There is also a need to assess the overall irrigation potential and to determine the likely impacts on water use and production in the Southeast.

1/ Underscored numerals enclosed in parentheses refer to entries in the References at the end of this publication.

Purpose and Objectives

This study is a part of a broader study of irrigation in the Southeast. Focusing on those factors which affect the temporal and spatial pattern of irrigation development in Florida, this study identifies areas of potential expansion in irrigated cropland acreages. Specific objectives are:

1. Analyze the importance of irrigation in Florida's agriculture.

2. Analyze the climatic, resource, and economic factors affecting use of supplemental irrigation.

3. Determine the physical and economic potential for irrigation in Florida.

Procedures and Data Availability

The study assumes that the growth of irrigated cropland in humid areas will most likely occur where climatic, resource, and economic factors are favorable to supplemental irrigation. Previous research has shown that the major factors influencing irrigation development are water availability, soil suitability, temperature, rainfall, irrigation costs and profitability of enterprises (2). Data showing increases in irrigated land over time are displayed in figure 1. Census of Agriculture data are used to present dot maps revealing the changing spatial pattern of irrigated agriculture between 1954 and 1978 (figs. 2 and 3). These maps depict the spatial distribution of irrigated cropland concentrated in central Florida where the Floridan aquifer provides abundant water for agriculture. These maps also present the patterns of irrigation development, including trends in total irrigated acres.

The incidence of drought, an important explanatory variable influencing irrigation development in Florida, was specifically measured by Palmer's drought index (14). The index can be used to identify areas which have experienced crop moisture stress and can benefit from supplemental irrigation and identify the amounts of water required to achieve adequate soil moisture levels. The plant's irrigation requirement is based on the difference between consumptive use (water requirements of the crop) and available rainfall.

The influence of urban development on irrigated cropland was analyzed with information from the Census of Population and Census of Agriculture. The Census of Population provides population information at 10-year intervals while the Census of Agriculture provides information at 4- or 5-year intervals. These two sets of data are not directly comparable. But, they can be used to assess the relationship between urban development and changes in irrigated cropland.

Data on consumptive use of water were obtained from several sources, including agricultural experiment stations located throughout the State. Empirical data from field offices were considered more reliable than theoretically developed information. Evapotranspiration estimates were developed for some locations from climate and soils data by several researchers (15, 16, 17, 19). Consumptive use requirements for selected crops, especially for citrus, vegetables, and sugarcane, were used to assess annual per-acre irrigation requirements. In addition, irrigation requirements for 90 percent of the time, 80 percent of the time, and 50 percent of the time are useful in selecting irrigation systems most suitable for specific areas. Information on irrigation systems was obtained from irrigation specialists, published studies, and related sources.

Information on soils suitable for irrigation was obtained from Prof. Carlisle of the Department of Soil Sciences at the University of Florida and other published sources. According to them, soils are not a restraining factor in Florida. Therefore, their distribution was not mapped for analysis.

Information on ground water supplies, obtained from the Florida Department of Natural Resources, Bureau of Geology, was placed on maps. Ground water sources supplied 41 percent of the total freshwater pumped in 1980 for irrigation purposes (4). The Floridan aquifer, the principal source of ground water in Florida, supplies most of the ground water used in the State. The Biscayne aquifer of southeast Florida, although limited in areal extent compared with the Floridan aquifer, is also a major source of ground water.

Information on costs and returns was obtained from the Florida Cooperative Extension Service.

HISTORICAL PERSPECTIVE

During 1954-82, Florida's irrigated area increased from 427,000 acres, peaked at 2 million acres in 1978, and then declined in 1982 to 1.6 million acres (table 1). In 1954, the leading irrigated crops were vegetables and orchard crops. By 1978, orchards, especially citrus crops, assumed first place in supplemental irrigation acreage. A major expansion in irrigation occurred around 1964 with a doubling of the area of irrigated vegetables and a quadrupling of irrigated fruit area, especially for citrus production. The acreage of major row crops such as corn has also increased rapidly in the past decade.

Onfarm cash receipts for Florida agricultural production in 1982 were $2.37 billion (1978 dollars), a 21.8-percent decrease from the 1978 value of $3.03 billion. The 1982 rankings for the onfarm cash value of Florida agricultural crops were: fruits, nuts, and berries, $656 million; livestock, poultry, and their products, $678 million; vegetables, sweet corn, and melons, $387 million; grains, tobacco, and sugarcane, $276 million; and nursery greenhouse crops, $342 million (26).

Irrigated farmland declined 407,554 acres between 1978 and 1982. Most of this decline is accounted for by a decrease in pasture irrigation. Favorable weather conditions in 1982 provided generally sufficient moisture for Florida pasture during the recent census year (table 1). Increased use of water for municipal and irrigation purposes has resulted in a decline in the ground water levels of as much as 150 feet or more in some areas of the Floridan aquifer, especially in areas where both irrigation and population are concentrated (32). Drought conditions prevailing during the 1981 summer months also contributed to the lowering of water tables. The declining of water tables influenced irrigators to apply water on their more valuable crops rather than on pasture. Irrigation of citrus continued to expand and accounted for 43 percent of Florida's overall irrigated cropland in 1982.

By the late 1930's, Florida surpassed California in the production of citrus and in the 1940's its production was larger than all of the other U.S. producing areas combined (6). The growth of citrus production is attributed to the following factors that have increased the demand for oranges: (1) consumers-perceived health qualities of citrus; (2) development of high-quality frozen orange juice concentrates; and (3) advertizing and promotion of citrus products (33). Approximately 95 percent of the oranges produced in Florida are processed

Table 1. Major irrigated crops, Florida, census years

Major crops	1954	1959	1964	1969	1974	1978	1982
			Acres				
Vegetables	145,766	133,209	218,607	231,149	186,379	291,370	250,181
Sweet corn	13,991	18,045	41,198	40,259	---	49,096	32,217
Soybeans	---	---	---	10,261	18,549	18,813	16,422
Irish potatoes	15,219	15,235	---	28,394	21,098	23,626	25,977
Corn (for all purposes)	4,274	2,966	4,692	15,413	20,334	41,594	64,711
Tobacco	4,758	7,645	9,712	9,355	5,880	6,237	5,636
Sugarcane	---	---	211,048	---	---	285,343	192,820
Land in bearing and nonbearing fruit orchards, groves, vineyards, and planted nut trees	89,474	106,328	422,310	543,096	549,758	646,949	681,910
Pasture	128,057	135,582	---	279,494	364,540	569,117	281,765
Other crops	26,268	129,738	309,625	207,785	392,197	58,923	31,875
Total irrigated acreage	1/427,807	413,526	1,217,192	1,365,206	1,558,735	1,991,068	1,583,514

--- = Data not available.
1/ Data may not add up to exact numbers because of the way double cropping was reported.
Sources: (21, table 9A, p. 151; 22 p. 110; 23, table 14, p. 440; 24, table 11; 25, table 10; 26, table 41).

as concentrate. As the demand for this product steadily increased, there was a corresponding increase in the acres of young irrigated citrus trees.

The moderating influence of the inland lakes is noticeable in the production of citrus and delicate vegetables because most of the orange groves and vegetable production are located south of water bodies. As in the case of citrus irrigation, vegetable production, especially tomatoes, has been influenced by improvements in the food processing industry and a favorable climate. In the 1920's, tomato production was scattered from Marion County in the north to the areas around Miami in the south. By 1964, this production had moved south of Lake Okeechobee. This trend is closely related to climatic patterns and the availability of new lands, according to Ward (33). The acreage of irrigated Irish potatoes and tobacco has remained stable while corn for all purposes is increasingly irrigated. Sweet corn irrigated acreage declined between 1978-82.

An important trend is the concentration of irrigated acreage on large farms, especially farms of 2,000 acres or more which comprise 4.6 percent of irrigated farms. Such farms accounted for 61 percent of the irrigated cropland in 1979 (27). Approximately 11,657 (26 percent) of the farms in Florida were irrigated in 1978 and more than half of these farms (57 percent) irrigated fewer than 40 acres (7). In 1982, irrigated farms of 2,000 acres or more numbered 400, accounting for 56 percent of the total irrigated land. By contrast, small farms of fewer than 70 acres accounted for only 4.5 percent of the total irrigated land (26).

U.S. Army Corps of Engineers projects are important in supplying irrigation water in central Florida, even though the Corps does not typically develop projects for irrigation. Authorized in the Flood Control Act of 1968, the Central Florida Project involved the construction of an interrelated system of canals, levees, pumping stations, and structures necessary to supply irrigation water, maintain optimum water levels, and remove flood waters in Martin County. The Central Florida Project provides water for about 100,000 acres of cropland with a total Federal investment of $15 million, $8.7 million of which were allocated to irrigation development (29).

Another important federally sponsored project having a direct impact on the agricultural economy of the area was the Central and Southern Florida Flood Control Project, begun in 1948. The Florida Flood Control District (FCD) was charged with meeting the need for flood protection and sufficient water supply, preventing saltwater intrusion, encouraging agricultural and urban development, and preserving fish and wildlife. In 1976, FCD was given new responsibilities to incorporate environmental concerns as well. Its mandate was enlarged to include all of southern Florida, and a new name was assigned to it: Florida Water Management District (34).

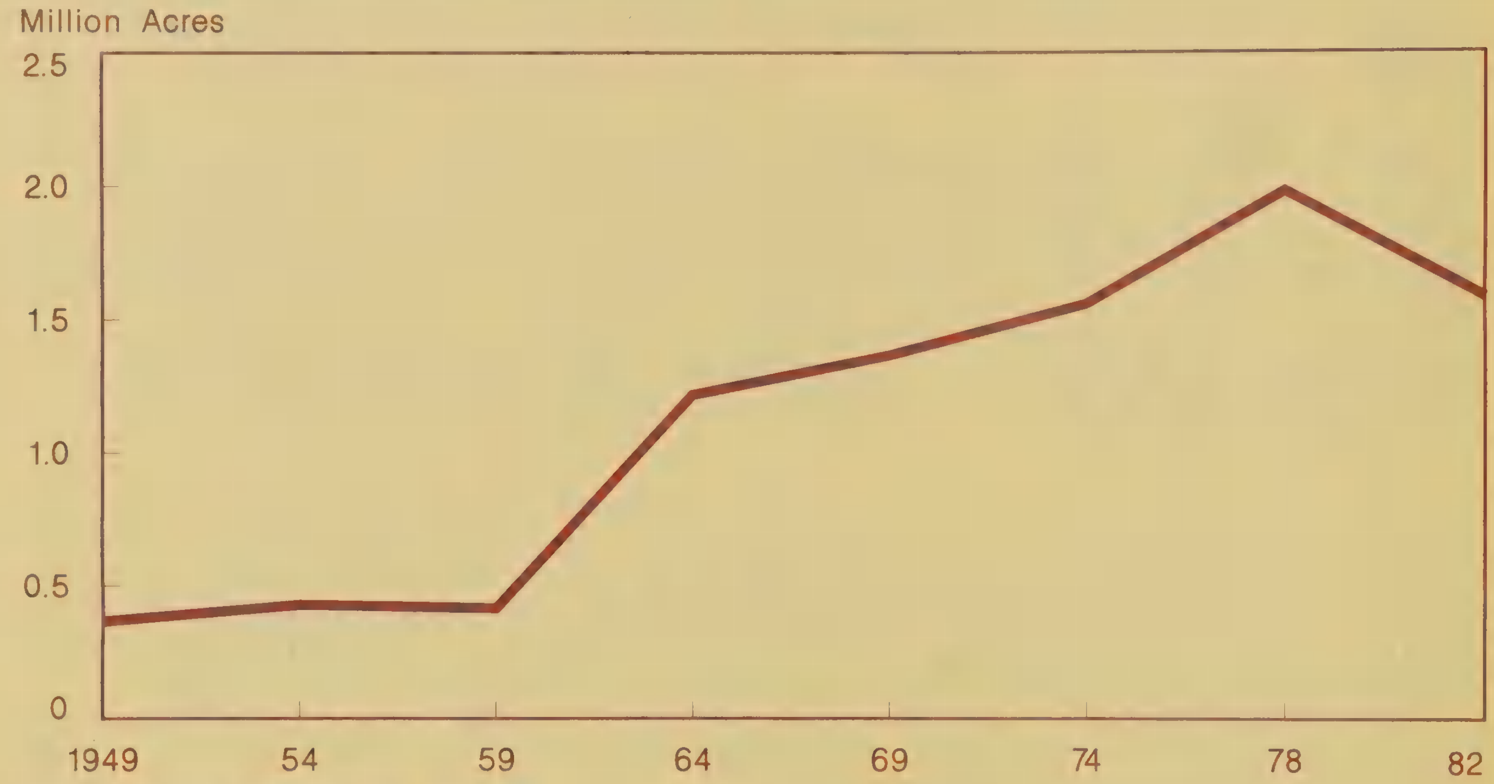
Trends in Irrigated Cropland in Florida

Total cropland in Florida, 3.4 million acres in 1954, increased by 18 percent to 4 million acres by 1982. Total harvested cropland in 1954 was 1.9 million acres and, according to census reports of 1982, increased by 37 percent to 2.6 million acres. Major harvested crop acreages in 1982 were: citrus, 916,000 acres; sugarcane, 344,000 acres; soybeans 334,000 acres; vegetables, 284,000 acres; corn, 217,000 acres; peanuts, 46,000 acres; and Irish potatoes, 31,000 acres. Hay was harvested from 282,000 acres in 1982.

Irrigated cropland increased consistently from 1960 to 1978 but declined in 1982 (fig. 1). There was a marked increase in both irrigated acres and the proportion of cropland irrigated during the early 1960's when the region experienced severe drought conditions. The upward trend in total irrigated land continued after 1964 but at a considerably slower rate than in the early 1960's.

Figure 1

Historic trend of irrigated land, Florida



Source: U.S. Census of Agriculture, 1949 through 1982.

The irrigation of cropland has been fairly concentrated. In 1954, extensive irrigated acreage in Palm Beach County accounted for 18 percent of the total irrigation acreage in Florida (table 2). St. Lucie, Indian River, Hillsborough, and Hendry counties were also important in irrigated land use. Almost two-thirds of the irrigation acreage was located in the 10 central and southern counties around Lake Okeechobee.

The location of irrigation development did not change significantly over the years. In 1982, irrigated cropland remained concentrated in roughly the same central and southern region as in 1954 with some change in the composition and ranking of the top 10 counties. These counties also accounted for approximately two-thirds of irrigated cropland (table 2). Palm Beach County absolutely overshadowed other counties with 25 percent of the irrigated acreage in 1978. It accounted for 19 percent in 1982 and was followed by Hendry and Polk counties with 9 and 8 percent, respectively.

Table 2. Leading counties in irrigated land, Florida

1954			1978			1982		
County by rank	Area	Percentage share	County by rank	Area	Percentage share	County by rank	Area	Percentage share
	Acres	Percent		Acres	Percent		Acres	Percent
Palm Beach	78,831	18.4	Palm Beach	490,075	25.0	Palm Beach	294,641	18.6
St. Lucie	42,160	9.9	Hendry	195,144	9.8	Hendry	142,302	9.0
Indian River	31,168	7.3	Polk	142,132	7.1	Polk	122,748	7.8
Hillsborough	21,779	5.1	St. Lucie	119,070	6.0	St. Lucie	105,546	6.7
Hendry	19,304	4.5	Indian River	88,553	4.4	Indian River	99,137	6.3
Polk	19,197	4.5	De Soto	79,553	4.0	Lake	71,514	4.5
Broward	18,666	4.4	Lake	72,332	3.6	Martin	61,115	3.9
Dade	17,087	4.0	Brevard	70,286	3.5	Glades	55,850	3.5
Orange	16,941	4.0	Martin	68,618	3.4	Hardee	48,126	3.0
Lee	15,198	3.6	Glades	61,183	3.1	Dade	47,819	3.0
Total for 10 counties	280,331	65.5		1,386,946	69.7		1,048,798	66.2

Source: (21, table 9A, p. 151; 25, table 10; 26, table 2, p. 133-137).

De Soto County appeared among the 10 leading counties in irrigation in 1978, when a large area of pastureland was irrigated. In 1982, very little pastureland was irrigated in this county; and, since its other crops' acreage did not increase greatly, De Soto did not appear in the list of 10 leading counties.

Most Florida counties registered a decline in irrigated cropland between 1978-82. Palm Beach County, for example, experienced a 40-percent decline from 490,075 acres in 1978 to 294,641 acres in 1982. Among the 10 leading counties in irrigation, Indian River was the only county which showed an increase in irrigated cropland during this period. Citrus growers of Indian River, through the Indian River Citrus League, have been able to obtain preferential prices for their fruit by emphasizing marketing and controlling product quality and appearance of fresh fruit shipped to northern cities.

Spatial Distribution of Irrigated Acreage

Irrigated acreage in 1954 was highly concentrated in the central counties around Lake Okeechobee with very little irrigated cropland in the northern and panhandle counties (fig. 2). By 1978, irrigated cropland remained highly concentrated in central Florida with some increase in the northern counties, especially St. Johns, Alachua, and Marion counties in northern Florida, and Jackson, Gadsden, and Santa Rosa counties in the panhandle region (fig. 3). Increases in the northern counties consisted primarily of irrigated corn and soybeans.

A significant feature of irrigation expansion in Florida has been the tendency for irrigation to expand in counties where irrigated cropland already exists. Favorable climate is the primary reason for the location of citrus and tropical fruit production in the central part of the State especially the Lake Okeechobee area where the weather is influenced by this large body of water. Citrus plants are extremely sensitive to low temperatures; mangoes and sugarcane are damaged when temperatures fall below freezing.

Sugarcane irrigation is concentrated south of Lake Okeechobee with a high proportion of the crop irrigated. Production of this crop reached a high of 430,000 acres in 1980 (7). However, recent Census of Agriculture data show a decline in sugarcane acreage. The muck soils in Hendry County and Palm Beach County, south of Lake Okeechobee, are highly suitable for sugarcane cultivation. Plantings of Valencia oranges have recently increased and are emerging as an important irrigated crop in the sandy soils in Hendry County.

Urban Expansion and its Influence on Irrigated Land Use

There are eight main urban centers in Florida, led by Miami in Dade County, the largest center in the State with a 1980 population of 1.6 million people (table 3). Urban areas in the State increased from 881,000 acres in 1960 to approximately 2.6 million acres in 1980. The population density of urban areas varied from 7.4 persons for Miami to 1.9 persons per acre in Melbourne-Cocoa (table 3). Population growth occurs at a rapid pace on the urban fringe of major cities such as Miami, Fort Lauderdale, and St. Petersburg which increases the population density and brings about major declines in cropland in some urban counties contiguous to main urban centers. The prospect of future conversion of land to urban development may undermine the longrun production of agricultural lands and cause the idling of more land than is needed for shortrun development.

Figure 2

Distribution of Irrigated Acreage in 1954 in Florida

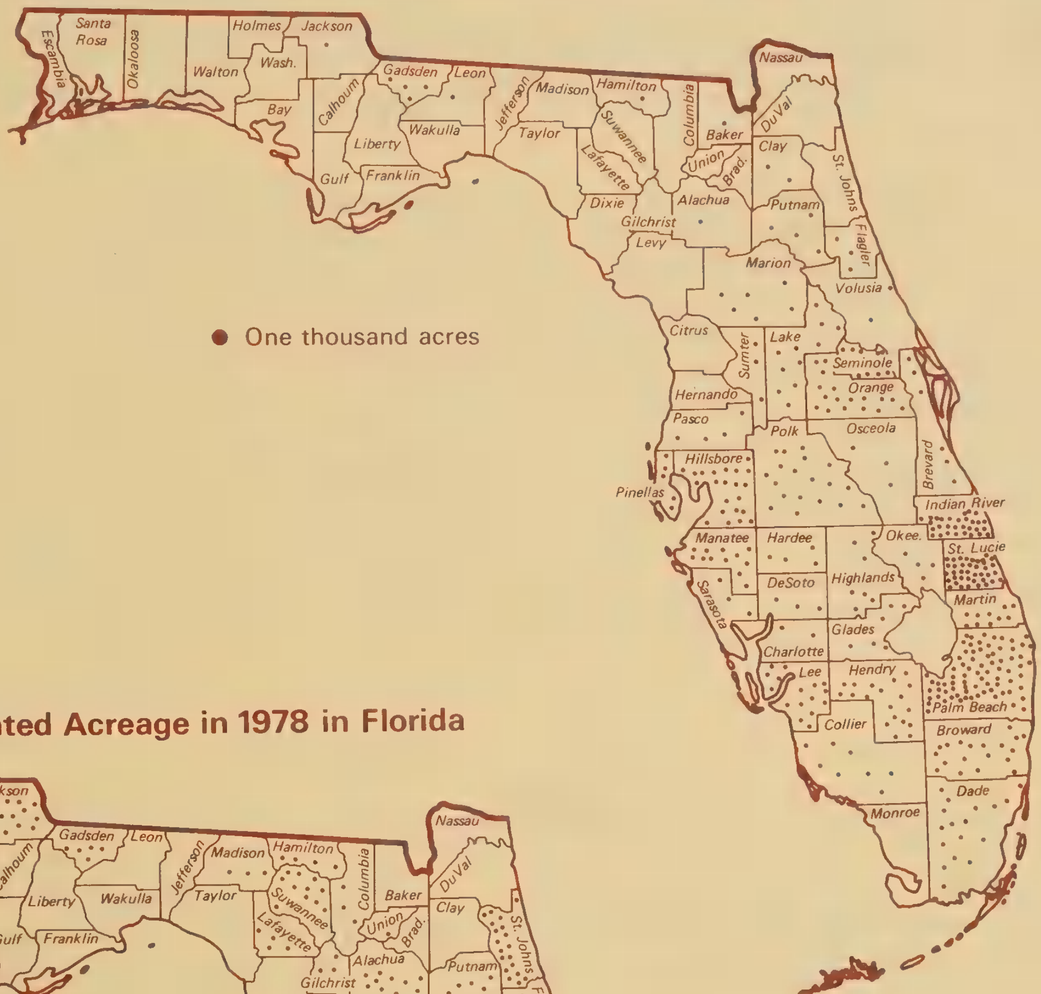
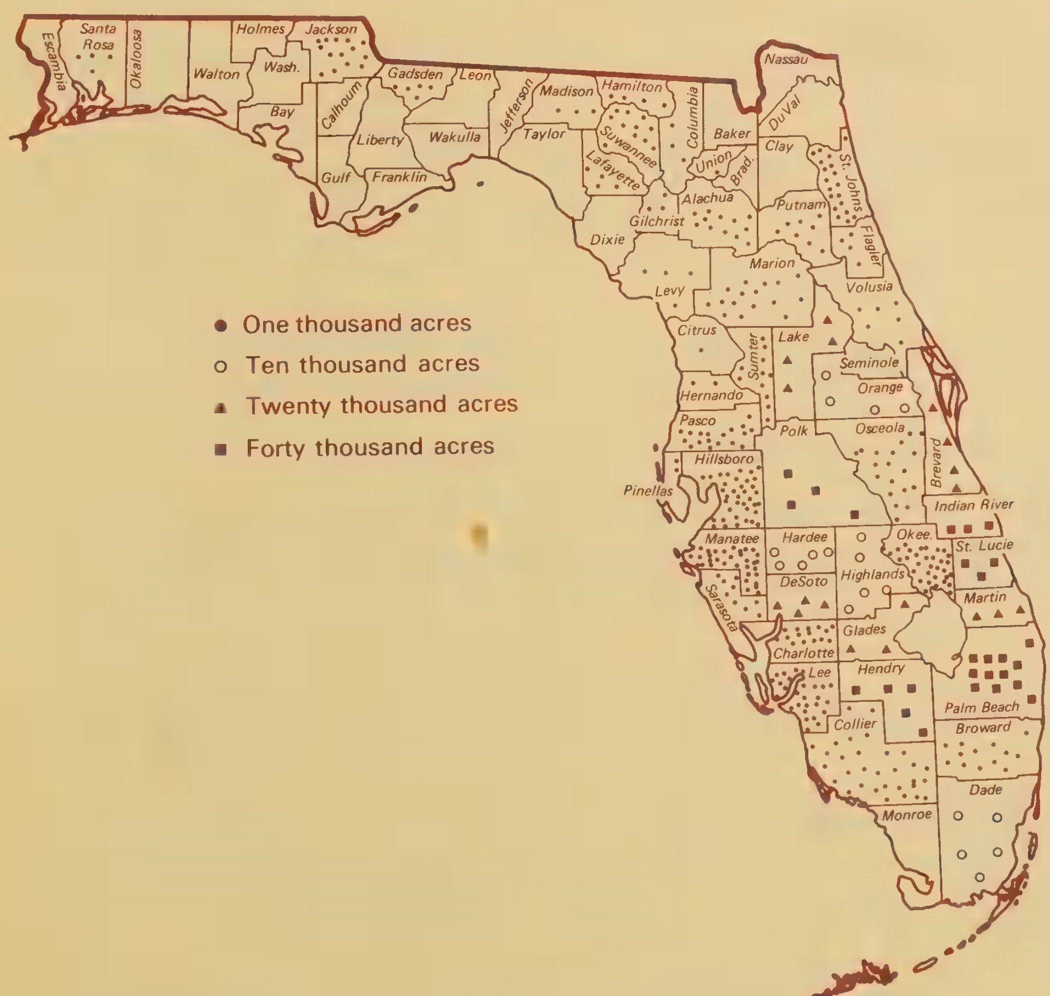


Figure 3

Distribution of Irrigated Acreage in 1978 in Florida



Harvested cropland over the period 1964-82 increased by 132 percent in Palm Beach County, while Dade and Duval counties showed increases of 1 and 15 percent, respectively. The remaining five counties registered a decline in the cropland harvested during this period (table 4). Cropland acreage in the eight-county area increased by 25 percent as a result of landclearing, drainage, and other land reclamation activities in Palm Beach County which more than offset the decline in cropland that occurred in the five counties that showed urban expansion.

Irrigated land use also increased in the same eight-county area, but at a much lower rate. Between 1964-82, irrigated land use increased by 22,475 acres or by 5 percent (table 5). If one considers a shorter span of time, for example, between 1978-82, irrigated land witnessed a sharp decline which is attributed to the reduction in pastureland irrigation. The largest percentage increase in irrigated acreage occurred in Brevard County, while Palm Beach County experienced the lowest percentage increase. Broward, Hillsborough, Orange, and Pinellas counties registered a decline in irrigated land use during the same intercensus period. Population increases in Palm Beach County did not greatly restrict increases in irrigated land use. Muck soils are increasingly brought under cultivation in the southwestern part of the county and are being improved through drainage. Recent freezes will probably trigger relocations of citrus groves to locations further south, where minimum temperatures do not fall below 28°F.

CLIMATIC RELATIONSHIPS

The characteristics of Florida's climate are primarily attributed to the State's latitude, its proximity to the Gulf of Mexico and the Atlantic Ocean, the influence of numerous lakes, and the passage of intense high- and low-pressure cells and related air masses across portions of the eastern United States. These factors combine to produce moderate temperatures and 40-50 inches of annual precipitation. This normal pattern is punctuated by unusual weather during the passage of extreme high- or low-pressure cells. March, April, and May are relatively dry in Florida during which a normal rainfall average of 2.3 inches per month is recorded. June through August months are warm and humid, with a mean temperature of approximately 82°F and an average rainfall of 4.6 inches per month.

Critical Climatic Factors and Irrigation

Citrus crops comprised 43 percent of the total irrigated cropland in Florida during 1982. The principal U.S. citrus-producing regions -- central Florida, south Texas, southeast Arizona-southern California -- range from C_2 (moist subhumid) through E (arid), according to the Thornthwaite classification of climates.2/ Temperature is the most crucial weather element for commercial citrus production in any of these regions. There are relatively similar temperature characteristics within these regions (table 6). In regions where rainfall variations are large, as in the dry West, citrus cultivation is totally irrigated.

2/ Thornthwaite's classification of climates is like Koppen's as it employs a symbolic nomenclature in designating complexly defined climatic types. Variations in climate are based on precipitation effectiveness and seasonal temperatures. Their meanings are: (A) rain forest, (B) forest, (C) grassland, (D) steppe, (E) desert. Those due to diminished temperature efficiency are: (A') tropical rain forest, (B') temperate rain forest, (C') microthermal rain forest, (D') taiga, (E') tundra, (F') perpetual frost (no vegetation).

Table 3. Major urbanized counties in Florida, 1980

County	Main metropolitan centers	Urban population 1/	Urban area 2/	Persons per acre
		Number	Acres	Number
Brevard	Melbourne-Cocoa	255,995	136,832	1.9
Broward	Fort Lauderdale	1,008,469	185,280	5.4
Dade	Miami	1,608,216	217,408	7.4
Duval	Jacksonville	561,485	263,424	2.1
Hillsborough	Tampa	560,473	173,632	3.2
Orange	Orlando	433,870	151,872	2.9
Palm Beach	West Palm Beach	535,409	147,200	3.6
Pinellas	St. Petersburg	724,988	154,304	4.7
Total		5,688,905	1,429,952	4.0

Source: 1/ (28).

2/ Area in urbanized areas and places of 2,500 or more population outside urbanized areas, developed by the Geography Division, Bureau of the Census.

January mean temperature is the most critical variable for citrus production since soil moisture stress conditions can be counteracted with irrigation water. To some extent, the effect of low winter temperatures and freeze can also be delayed by raising the temperature a few degrees by heating equipment, water application, or use of fans to mix the upper air with the colder air at the surface. The temperature for citrus cultivation should remain above 26° F. Subtropical fruits, including mango production, usually require above freezing temperatures. One of the important irrigated crops, sugarcane, has a low tolerance for cold temperatures.

Another significant climatic variable with direct relationship to irrigation growth is the incidence of droughts. The most rapid growth in irrigation took place during 1960-64 (fig. 1), precisely when the region experienced a prolonged drought (table 7). Palmer's drought index showed a reading of -3.74 for the month of May 1962, which represents a severe drought condition. The lowest index reading (-3.94) appeared in July 1981; but there was sufficient precipitation in the next year.

Table 4. Cropland harvested in urban counties, Florida

County	1964	1974	1978	1982	Percentage change, 1964-82
	Acres				Percent
Brevard	21,652	18,330	19,631	19,713	-9
Broward	19,652	12,272	17,583	9,102	-54
Dade	58,171	55,730	64,084	58,940	1
Duval	5,139	3,713	4,454	5,898	15
Hillsborough	82,239	58,274	58,223	64,528	-22
Orange	151,895	84,728	73,532	67,465	-56
Palm Beach	192,125	277,100	452,142	446,263	132
Pinellas	9,174	5,747	5,371	3,730	-59
Total	540,047	515,894	695,056	675,639	25

Sources: (23, 24, 25, 26).

Table 5. Irrigated land in urban counties, Florida

County	1964	1974	1978	1982	Percentage change, 1964-82
	Acres				Percent
Brevard	3,870	43,925	70,286	16,050	315
Broward	19,964	7,961	13,971	3,144	-84
Dade	36,625	44,469	49,874	47,819	31
Duval	516	228	189	655	27
Hillsborough	43,018	26,359	34,938	39,174	-9
Orange	70,384	37,738	40,335	37,991	-46
Palm Beach	238,395	308,346	490,075	293,463	23
Pinellas	4,398	2,130	2,088	1,349	-69
Total	417,170	471,156	701,756	439,645	5

Note: The fact that irrigated acreages recorded in Brevard and Palm Beach counties are larger than harvested cropland is due to the large area of irrigated pasture.

Sources: (23, 24, 25, 26).

Table 6. Climatic data for selected areas

Item	Riverside, California	Indio, California	Yuma, Arizona	Tempe, Arizona	Weslaco, Texas	Lake Alfred, Florida	Orlando, Florida
			Degrees/minutes				
Latitude	33° 58'	33° 43'	32° 40'	33° 23'	26° 09'	28° 09'	28° 33'
			Degrees Fahrenheit				
Jan. mean temp.	52.0	54.2	53.5	49.8	61.7	62.9	60.5
July mean temp.	75.6	92.5	91.1	88.9	84.7	82.4	82.0
Maximum temp.	118	125	118	115	110	103	103
Minimum temp.	21	13	19	20	21	23	18
			Days				
Length of growing season	265	299	320	265	314	334	314
			Inches				
Average annual precipitation	11.5	3.2	4.0	7.0	24.0	51.1	51.5

Source: (13).

Table 7. Drought indices for central Florida computed by Palmer's method

Year	April	May	June	July	August	September
1960	4.09	3.65	3.23	4.67	3.88	5.27
1961	- .95	- .57	-1.10	-1.92	-1.70	-2.77
1962	-3.56	-3.74	-2.90	-3.25	.59	1.03
1963	-1.50	- .03	-1.00	-1.30	-1.85	-1.51
1964	- .80	- .81	-1.51	-1.73	-1.61	-1.75
1965	-2.38	-3.07	-.29	1.10	- .15	- .58
1966	.88	1.00	1.64	.38	- .39	- .75
1967	-2.79	-3.56	-3.08	-2.77	-1.62	-2.05
1968	-3.30	.47	2.26	2.25	1.70	1.12
1969	- .75	- .29	- .54	- .98	.53	.40
1970	-1.09	- .65	-1.08	-1.64	-1.93	-2.26
1971	-3.50	-3.40	-3.52	-3.34	-2.77	-2.58
1972	-1.56	-1.21	- .71	-1.81	-1.67	-3.01
1973	- .03	- .13	- .60	- .16	- .07	- .10
1974	-2.50	-2.60	1.64	1.95	- .10	- .64
1975	-3.06	-2.59	-2.71	-2.38	-2.49	-2.24
1976	-3.06	1.50	1.87	- .60	- .73	- .73
1977	-1.76	-1.84	-2.34	-2.50	-2.30	-2.28
1978	-1.01	.33	.33	.73	- .37	-1.29
1979	-1.13	2.08	- .71	-1.34	.28	1.77
1980	.12	.64	- .66	-1.21	-1.68	-2.23
1981	-3.02	-3.27	-3.15	-3.94	-2.50	-2.68
1982	.75	1.68	2.35	2.05	1.72	1.85

Source: Method from (14).

The 1961-65 drought was of both long duration and intensity and the correlation between irrigation growth and drought for that period is strong. During the intercensus 5-year period of 1959-64, irrigated cropland tripled, with citrus irrigation showing the largest absolute increase. Again, drought conditions existed in 1967 and 1969-77. The drought ending in 1977 was spread over large areas of the Nation. Two-thirds of the Nation's 3,005 counties were on the Federal "drought impact" list by midsummer. The Southeast, particularly from North Carolina to Florida, experienced severe drought conditions.

Adjustments to Freeze Hazard

To combat radiation frost and freezing, farmers usually employ the following: (1) heating equipment, (2) wind machines, and (3) water protection. Farmers often adopt these measures in combination and rarely do they apply only a single method for avoiding freezes.

Sprinkler irrigation is used to protect plants. The water must be applied uniformly to all parts of plants during the cold period or more damage might

occur than if the water were not applied. The practice is based upon the principle that heat is released when water changes from a liquid to a solid state. The heat released as the water freezes acts to keep the temperature of the plant near or above freezing.

Consumptive Use of Water for Selected Crops

In computing measures of potential evapotranspiration or consumptive use of water by crops, one assumes that sufficient soil moisture is available for plant growth. Whenever soil moisture stress develops, irrigation water can be applied to restore soil moisture to the base level or field capacity.3/ Efficient use of irrigation water in the field requires information on water requirements of specific crops.

A review of the various methods for measuring potential evapotranspiration, consumptive use, and irrigation requirements for selected crops are discussed by Bajwa, Crosswhite, and Gadsby (3). Data for evapotranspiration or consumptive use of water for citrus, pastures, sugarcane, and rice are presented in table 8. Sugarcane, with 48.5 inches of consumptive water use, has the highest annual consumptive use of water in the Everglades agricultural area. Rice, a staple crop with 8.43 inches of consumptive use of water for July, has the highest use for any 1 month. Citrus, another plant group which grows throughout the year, has an annual consumptive use of 44.58 inches of water.

Irrigation requirements for oranges and lemons are highest with 18.3 inches at Ft. Pierce and lowest at Lake Alfred with 11.4 inches (table 9). Annual irrigation requirements for vegetables at Ft. Pierce are 16.5 inches of water for 80 percent of the time and about 18.5 inches 90 percent of the time (table 10).

Table 11 indicates the consumptive use figures for sugarcane grown in the Everglades agricultural area. For this location, annual consumptive use of water for sugarcane is 48.5 inches and net irrigation requirements are calculated to be 17.5 inches.

WATER USE AND SOURCES OF WATER SUPPLY

The total water withdrawal from different sources in Florida in 1980 was 23.76 million acre-feet per year, including 15.57 million acre-feet from saline sources. Total fresh water withdrawn in 1980 for agricultural and other economic activities was 8.19 million acre-feet, according to a State Natural Resources and Bureau of Geology Survey (4). Almost 74 percent of all daily water use in 1980 was for thermoelectric power generation; 65 percent of the total water

3/ 1. Potential evapotranspiration (PE) is defined as the maximum quantity of water transferred as water vapor from the ground surface and associated plant environment under ideal conditions of soil moisture and vegetation cover.
2. Consumptive use of water by crops is defined as that part of soil moisture that is actually used by plants under relatively favorable soil moisture conditions.
3. Soil moisture stress is defined as a condition of moisture in the soil in which the plants show less activity in their growth or plants start wilting.
4. Field capacity of soils is that condition of a soil when no further addition of moisture will remain in the upper layers.

Table 8. Consumptive use of water by crops in Everglades agricultural area

Month	Citrus 1/	Pasture 2/	Sugarcane 3/	Rice 4/	Rainfall 5/	Pan evapo transpiration 6/
			Inches			
January	2.09	2.01	1.42	0	1.97	3.39
February	2.60	2.52	1.10	0	1.97	4.00
March	3.58	3.35	2.52	0	3.21	5.70
April	4.49	4.21	3.39	1.63	2.96	6.54
May	5.31	5.20	4.80	3.07	4.74	7.06
June	4.41	4.25	5.98	5.82	9.08	6.24
July	4.88	4.80	6.50	8.43	8.58	6.36
August	4.80	4.80	6.69	3.05	8.21	6.12
September	4.02	3.86	5.12	(5.00)	8.82	5.31
October	3.59	3.43	5.20	(3.00)	5.65	4.82
November	2.72	2.48	3.19	0	1.74	3.71
December	2.09	1.93	2.59	0	1.80	3.19
Total	44.58	42.84	48.50	22.00	58.76	62.44

1/ Data provided by, USDA and Florida Agr. Exp. Sta. Project, Ft. Pierce (unpublished).
2/ (19).
Mean monthly values averaged over 5 years and averaged over water table depth of 12, 24, and 36 inches maintained in lysimeters at Ft. Lauderdale. These turfgrass evapotranspiration values are assumed to be valid for pastures adequately supplied with water.
3/ (16).
4/ (17).
Assuming planting date of April 15 which is approximately the middle of the planting season. Values in parentheses are estimates for a ratoon crop. Rice is not always ratoon cropped.
5/ Belle Glade Weather Records, University of Florida: AREC, P.O. Drawer A, Belle Glade, FL 33430.
6/ Pan evaportranspiration is a measure of the capability of the air to evaporate water. A relatively higher reading indicates relatively high consumptive use of water.

withdrawn for this purpose was from saline sources. Irrigation accounted for only 14 percent of the total water withdrawals. Detailed data for uses by county are given in the appendix.

Irrigation Water Use in Florida

Annual irrigation water withdrawls in Florida were 3.4 million acre-feet in 1980, of which 1.7 million acre-feet represented consumptive use. In the 10 leading irrigation counties, withdrawals amounted to 2,317,000 acre-feet of irrigation water in 1980 (table 12). This is 68 percent of the Florida's irrigation water use. Palm Beach County was an important user with 688,390 acre-feet of water applied in 1980. For the entire State, ground water sources accounted for 1.8 million acre-feet while surface sources supplied around 1.6 million acre-feet of water for irrigation.

Table 9. Computed annual water consumptive use or evapotranspiration for selected locations and net irrigation requirements for citrus 1/

Location	Average annual rainfall	Grapefruit ET	Grapefruit NIR-50 2/	Grapefruit NIR-80 2/	Oranges and lemons ET	Oranges and lemons NIR-50 2/	Oranges and lemons NIR-80 2/
	Inches						
Belle Glade	58.75	47.3	12.3	16.9	40.0	7.6	11.9
Bradenton	55.14	47.1	13.9	18.6	39.9	9.3	13.4
Clermont	51.23	47.6	13.7	18.7	40.3	8.1	12.8
Ft. Myers	53.34	48.2	15.7	18.2	40.2	10.7	15.0
Ft. Pierce	55.27	48.3	20.6	24.4	40.9	14.3	18.3
Gainesville	52.45	45.8	13.8	18.4	39.0	8.3	12.7
Lake Alfred	52.78	47.3	11.9	17.0	40.0	6.6	11.4
Mountain Lake	53.83	47.4	12.2	17.2	40.1	6.7	11.7
Pompano Beach	62.50	48.9	13.4	17.9	41.4	8.3	12.6
Titusville	55.96	47.1	13.5	18.2	39.9	8.3	12.7

1/ Computed by procedures described in SCS Technical Release 21, 1967.

2 NIR-50 and NIR-80 are the average net irrigation requirements that would be adequate 50 percent and 80 percent of the time. More water would have to be applied to the crop than the net irrigation requirements to account for evaporation, runoff and perculation below the root zone.

Two million acres of irrigated cropland in Florida in 1980 received a total of 3.4 million acre-feet of water, according to 1980 estimates by the U.S. Geological Survey. This was an average annual application of 1.7 acre-feet of water with an average consumptive use of water of only 0.85 acre-feet. By contrast, average annual application was 1.2 acre-feet in Texas (18).

Florida applies more irrigation water per acre than does Texas, even though it rains more in Florida. Citrus, sugarcane, vegetables, and tropical fruits are grown in Florida almost year-around and have high water use rates compared with grain crops. The widespread existence of sandy soils in Florida encourages frequent irrigation water applications for crop production, as these soils tend to lose water through rapid downward percolation and higher evapotranspiration rates. Most Texas irrigation water is applied to cotton, sorghum, corn, and wheat which have shorter growing seasons than the main irrigated crops grown in Florida. Higher rates in Florida are due to relative abundance of available, easily accessible water supplies, high evapotranspiration, and poor waterholding qualities of sandy soils.

Sources of Water Supply

Florida is a water-rich State, with an average annual rainfall of about 53 inches and some of the most productive aquifers in the Nation. Both Florida's population and freshwater use nearly doubled from 1960-80. The principal source of ground water in Florida, the Floridan aquifer, supplies most of the water used in the State (fig. 4). The Biscayne aquifer of southeast Florida,

Table 10. Consumptive use of water for vegetable production at selected levels of adequacy, Ft. Pierce, 1925-81 average

Month	ET	NIR-50 1/	NIR-80 1/	NIR-90 1/
		Inches		
January	2.7	1.3	1.5	1.6
February	2.7	1.0	1.2	1.3
March	3.4	1.4	1.7	1.8
April	3.7	1.6	1.9	2.0
May	4.8	1.8	2.2	2.4
June	4.8	.8	1.4	1.6
July	5.2	1.4	1.9	2.2
August	5.1	1.3	1.8	2.1
September	4.5	0	.2	.5
October	3.5	0	0	.2
November	2.9	1.2	1.4	1.5
December	2.6	1.1	1.3	1.5
Total	45.9	12.9	16.5	18.5

1/ Net irrigation requirement (NIR) is the net irrigation requirement that would be adequate 50 percent, 80 percent, and 90 percent of the time.

Source: UF WRC-2 and ARS Lysimeter, Ft. Lauderdale.
NOAA 53.07 average annual rainfall, Ft. Pierce, and SCS-21.

although limited in areal extent compared with the Floridan aquifer, is also a major source of ground water. Other principal aquifers include the Sand-and-Gravel aquifer of western panhandle Florida and the smaller, surficial, and intermediate-depth aquifers located beneath much of coastal and southern Florida. Water occurs under either confined or unconfined conditions. Where supplies must come from the surficial and intermediate aquifers, well yields are low. In others, especially where the Floridan and Biscayne aquifers occur, hundreds and even thousands of gallons of water per minute can be obtained per well.

In the western panhandle, the Sand-and-Gravel aquifer is the primary source of water; yields from this water supply are limited. The Biscayne aquifer is the primary source of drinking water for all municipal water supplies south of Martin County. The unconfined Biscayne is affected by a system of canals used for water-level control and flood prevention. These canals also serve as local sources of recharge.

Total water withdrawn from Florida aquifers in 1980, the most recent complete record for the State, was 3,758 million gallons per day (MGD), according to estimates made by Healy (10). Ground water sources supplied almost 87 percent of the total demand for public water supply and 94 percent of the rural domestic water use in 1980.

Table 11. Water consumptive use or evaportranspiration of sugarcane for the Everglades area

Month	ET 1/	NIR-80 2/
	Inches	
January	1.4	0.5
February	1.1	.5
March	2.5	.9
April	3.4	1.8
May	4.8	1.7
June	6.0	1.2
July	6.5	1.6
August	6.7	1.7
September	5.1	.7
October	5.2	2.2
November	3.2	1.7
December	2.6	1.5
Total	48.5	17.5

1/ Calculated from SCS-21 procedures for effective rainfall from Everglades data.

2/ NIR-80 is the net irrigation requirement that would be adequate 80 percent of the time. That is, in 2 out of 10 years, one might expect to need this much or more net irrigation water application.

Source: (15).

SOILS SUITABLE FOR IRRIGATION

The prime land in the State is located in the panhandle counties.4/ Most fertile soils are associated with the Dothan-Orangeburg-Fauquay association, but irrigated cropland on these soils has not expanded. Most irrigated cropland is located around Lake Okeechobee where sandy and loamy soils associated with central and south Florida flatwoods are predominant. This is also the location of muck soils most suitable for sugarcane and vegetables. These soils are extensively found in Palm Beach and Hendry counties. Major crops grown in central and south Florida are citrus, sugarcane, and vegetable crops which require warm temperatures to flourish.

The soils of Florida exert only a limited influence on the development of irrigated cropland in the State. Soils of the panhandle counties are suitable for row crops such as corn and soybeans. However, the recent Census of Agriculture data indicate that sweet corn and soybean acreage in Florida declined

4/ Personal communication with Victor Carlisle, Department of Soil Sciences, University of Florida, Oct. 1984.

Table 12. Water withdrawals in 10 leading irrigation counties, Florida, 1980

Location	Water use in irrigation	
	Use per day	Use annually
	Mil. gallons	Acre-feet
Palm Beach	614.23	688,390
Indian River	278.28	311,710
Hendry	243.53	273,020
St. Lucie	231.28	259,160
Brevard	166.76	186,880
Martin	138.93	155,855
Glades	124.22	139,065
Orange	93.47	104,755
Dade	89.58	100,375
Highlands	87.56	98,185
Total	2,067.84	2,317,395

Source: (4).

between 1978 and 1982. Irrigated cropland in Florida will likely be associated with specialty crops which have a large national market and high per-acre value of harvested output.

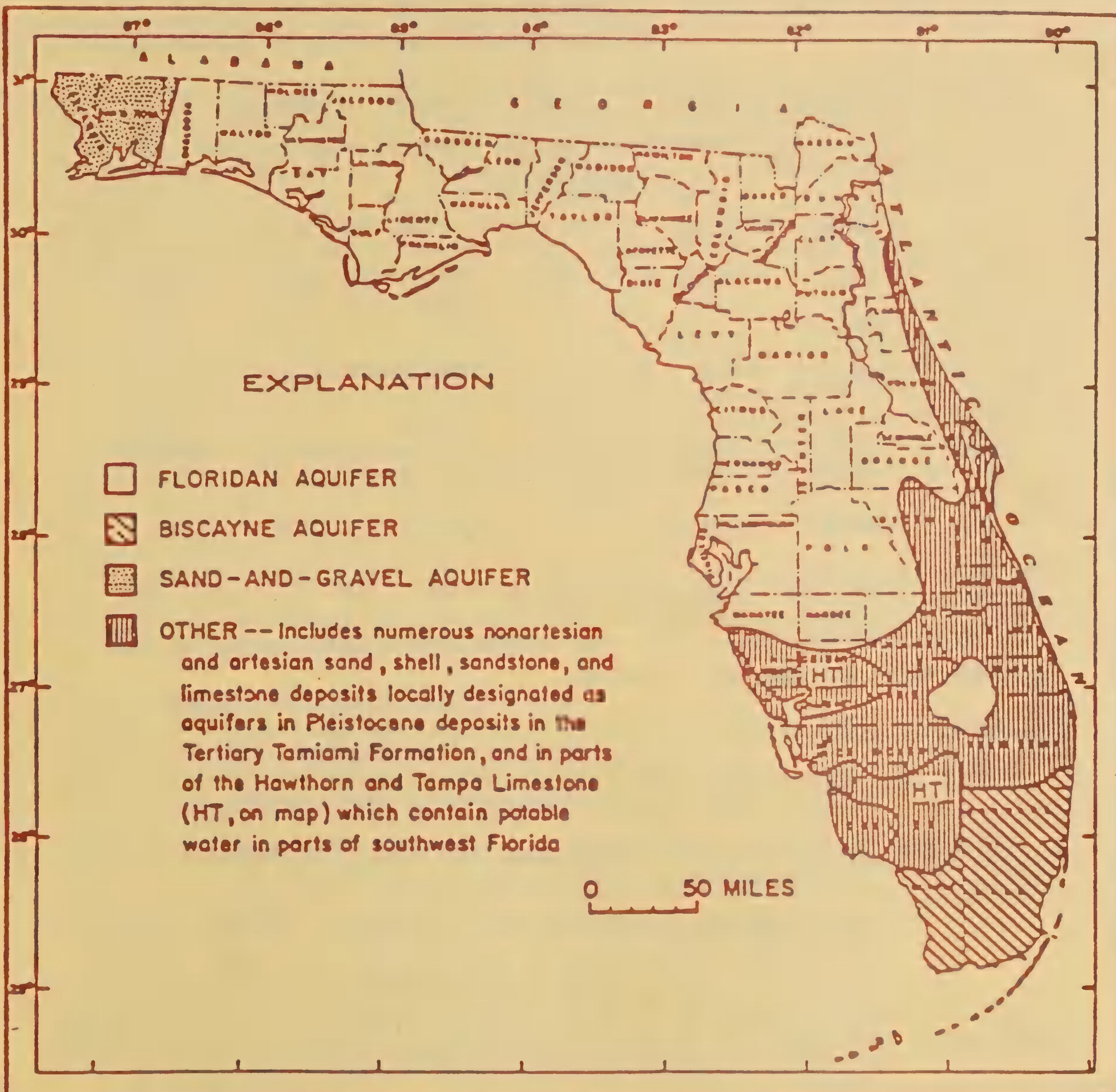
There are 2.52 million acres of class I, II, and III land in crops in Florida, according to the 1982 National Resources Inventory (NRI). Pasture acreage in the same three categories is 1.75 million acres, with a total of 11.5 million acres of land in the three classes (table 13). Florida is a region where many soils, such as those that need drainage, have generally been made productive through proper management of soils and water. Thus, the amount of land suitable for irrigation development in Florida is much greater than would appear to be the case, and is in the neighborhood of 2.5 million acres. The soils of the panhandle counties are quite suitable for irrigation, but so far irrigated cropland has not expanded significantly there.

ECONOMICS OF IRRIGATION

Costs of Irrigation

The major irrigation systems in use in Florida in 1968 were permanent overhead sprinklers, self-propelled traveling high-pressure guns, portable high-pressure guns, and perforated pipe sprinklers. Total annual costs (fixed and variable) ranged from \$59 to \$73 per acre or an average of about \$5 per acre-inch of water applied in 1968. These costs were three to four times higher in 1983 than 1968 as expressed in 1983 dollars (8). These ranged between \$159 to \$223 per acre, or about \$23 to \$27 per acre-inch of irrigation application. The cost increases are partly due to inflation, with an inflation factor of 1.87 during this time.

Figure 4



Source: (11).

Table 13. Land cover/use of nonfederal land and small water, by land capability class and subclass, Florida, 1982 1/

Class and subclass 2/	Cropland	Pasture-land	Rangeland	Forest land	Minor land cover/uses	Total
			1,000 acres			
I	66.6	11.3	0	19.4	0	97.3
IIe	268.5	101.2	.4	359.4	14.6	744.1
IIW	62.5	54.1	2.6	342.1	7.8	469.1
IIS	174.5	72.0	3.1	244.1	4.4	498.1
IIC	0	0	0	0	0	0
ALL II	505.5	227.3	6.1	945.6	26.8	1711.3
IIIe	94.0	53.8	0	164.7	4.4	316.9
IIIW	1,132.1	1,022.9	948.9	2,105.8	1,486.7	6,696.4
IIIS	718.4	440.1	50.6	1,362.5	64.9	2,636.5
IIIC	0	0	0	0	0	0
ALL III	1,944.5	1,516.8	999.5	3,633.0	1,556.0	9,649.8
I, II, and III	2,516.0	1,755.4	1,005.6	4,598.0	1,582.8	11,458.4

1/ Water body with fewer than 40 acres.

2/ Class I. Soils have few limitations that restrict their use.

Class II. Soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.

Class III. Soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.

Subclasses are soil groups within one class; they are designated by adding a small letter, e, w, s, or c to the class numerals, for example IIe. The letter e shows that the main limitation is risk of erosion unless close-growing plant cover is maintained; w shows that water in or on the soil interferes with plant growth; s shows that the soil is limited mainly because it is shallow, droughty or stony; and c shows that the chief limitation is climate that is too cold or too dry.

Source: (31).

Another important factor influencing the operational costs of sprinkler irrigation systems is the increased costs of fossil fuels in the United States. For example, the cost of diesel fuel increased from $0.37 per gallon in 1974 to $1 per gallon in 1980 (30), an inflation factor of 2.7.

Use of trickle irrigation systems with spray jets has been increasing during the last 6 years. These systems provide advantages of both lower initial and operating costs, compared with permanent sprinklers and traveling gun systems. The trickle system reduces water use per acre for citrus and orchard crop production. Water is released into or very near the crop root zone, thus reducing evapotranspiration losses as well as losses from excessive wind drift. An additional major advantage of trickle irrigation systems is that they also provide a measure of cold protection for the citrus crop. Under-tree, spray jets reduce freeze damage from radiation frost.

Irrigation costs for row crop production in the northeast and northwest sections of Florida vary widely between irrigation methods. Irrigation application costs ranged between $10.37 per acre-inch for low-pressure center pivot systems to $17.83 per acre-inch for the traveling gun system (table 14). A center pivot system (medium pressure) for 138 acres had an investment cost of approximately $57,100, and annual operating cost of $9,791.34 (table 15). Costs of various other irrigation systems are provided in tables 16, 17, and 18.

Costs of Sprinkler Systems

Two types of sprinkler irrigation systems have been extensively used in Florida orchard crops: traveling gun sprinkler and permanent overhead sprinkler systems. Cost estimates are outlined in table 19.

Costs of Trickle Irrigation Systems

From 1978 to 1980, approximately 69,000 acres of trickle irrigation were developed for Florida citrus groves and an additional 60,000 acres are currently being developed for irrigation with trickle irrigation systems. Trickle irrigation is usually combined with under-tree, spray jet systems which provide cold protection during radiation freezes. This feature made under-tree, spray jet systems the most popular type of trickle irrigation systems in Florida for citrus and orchard crops. A detailed cost analysis for trickle systems suitable for irrigating 40 acres of citrus with 7 inches of water per year is given in the appendix.

Yield Response to Irrigation

Research in Florida indicates that average yield increases of 35 to 47 percent can be expected from sprinkler irrigation of oranges and grapefruit, respectively. These yield increases occur on sandy soils where waterholding capacities are usually low.

Citrus varieties respond differently to irrigation. Yield responses from irrigation over a 6-year period were significant for Hamlin and Valencia oranges, and Marsh grapefruit on rough lemon rootstock. These varieties were irrigated at a rate of 1/3 depletion of available soil moisture in the first 5 feet of Astatula fine sand from January to June and at a 2/3 depletion rate for the remaining part of the year. Yield increases were 35 percent, 29 percent, and 47 percent for Hamlin and Valencia oranges and Marsh grapefruit, respectively. Pineapple orange trees yield increases of 10 percent were not statistically significant.

Table 14. Irrigation costs for row crop production, north and northwest Florida, 1981

Type of system	Fixed costs	Operating cost	Total costs	Unit costs 1/
	------- Dollars per acre -------			Dollars per acre-inch
Center pivot 2/	50.46	20.49	70.95	11.82
Center pivot 3/	45.36	16.84	62.20	10.37
Traveling gun 4/	50.99	42.71	93.70	15.62
Traveling gun 5/	66.54	40.44	106.98	17.83

1/ Based on six, 1-inch applications per year.

2/ $57,100 initial costs for pump, well, power unit, and system for 138 acres irrigated of 160 ac. field (medium pressure, 80 psi at pivot).

3/ $51,800 initial costs for pump, well, power unit and system for 138 acres irrigated of 160 ac. field (low pressure, 40 psi at pivot).

4/ $39,750 initial costs for pump, well, pipe, power unit, and system for 100 acres (cable tow).

5/ $48,618 initial costs for pump, well, pipe, power unit, and systems for 100 acres (hardhose).

Source: (9).

Yields of field corn for grain in 1982 increased by 34 bushels to 90 bushels on the average, while soybean yield increased from 25 to 28 bushels with proper irrigation. Irish potatoes showed a marked increase of 49 cwt per acre, with an average yield of 218 cwt per acre on irrigated fields.

Net returns attributed to irrigation water use are calculated for selected crops based on 1982 costs and price data. Dry cropland budgets for citrus, vegetables, and sugarcane are not available for comparisons with irrigated citrus, vegetables, and sugarcane budgets. For potatoes, an increase in net return of $606.25 per acre is attributed to the use of irrigation, while irrigation of soybeans exhibits a net loss of $54.60 per acre (table 20). Corn shows a net increase in returns of $17.25 per acre resulting from irrigation.

Costs and Returns for Selected Crops

Understanding the potential for irrigation practices requires specific knowledge of the profitability of various irrigated crops, and the impact that this will have on the adoption of irrigation. Therefore, the returns from selected crops are discussed below.

Table 15. Costs of a pivot system (medium pressure) 138 acres, one pivot, six applications of 1 inch each, 1981

System	Investment costs	Annual costs
	Dollars	
Well, 12"; 400' (20 years, S.L. depreciation) 1/	8,800	440.00
Pump, includes gearhead 2/ (800 gpm, 250 ft. TDH) (15 years, S.L. depreciation)	8,500	566.67
Power unit, 75 hp (12 years, S.L. depreciation)	9,800	816.67
Center pivot system, includes freight and installation (15 years, S.L. depreciation)	30,000	2,000.00
Diesel fuel, 4.4 gal./hr., 420 hrs. pumping time, fuel @ $1.20/gal.		2,217.00
Oil, 72 gal. @ $6/gal.		432.00
Repairs, 4.2 hrs. @ $15/hr.		63.00
Labor, 33 hrs. @ $3.50/hr.		115.50
Interest on investment, well, pump, power unit, system charged @ 10 percent		2,855.00
Taxes and insurance charged @ 0.5 percent of investment		
Total costs	57,100	9,791.34
Annual operating costs/acre		20.49
Annual fixed costs/acre		50.46
Total annual costs/acre		70.95
Cost per acre-inch		11.82

1/ Straight-line depreciation.
2/ T.D.H., total dynamic head or the head against which the pump is operating.

Source: (9).

Table 16. Costs of a center pivot system (low pressure) 138 acres, one pivot, six applications of 1 inch each, 1981

System	Investment costs	Annual costs
	Dollars	
Well, 12"; 400' (20 years, S.L. depreciation)	8,800	440.00
Pump, includes gearhead (800 gpm, 160 ft. TDH) (15 years, S.L. depreciation)	7,000	466.67
Power unit, 50 hp 12 years, S.L. depreciation)	6,000	500.00
Center pivot sytems, (low pressure); ind. freight and installation (15 years, S.L. depreciation)	30,000	2,000.00
Diesel fuel, 3.4 gal./hr., 420 hrs. pumping time, fuel @ $1.20/gal.		1,713.60
Oil, 72 gal. @ $6/gal.		432.00
Repairs, 4.2. hrs. @ $15/hr.		63.00
Labor, 33 hrs. @ $3.50/hr.		115.50
Interest on investment, well, pump, power unit, and system @ 10 percent		2,590.00
Taxes and insurance charged @ 0.5 percent of investment		259.00
Total costs	51,800	8,517.77
Annual operating cost/acre		16.84
Annual fixed costs/acre		45.36
Total annual costs/acre		62.20
Costs per acre-inch		10.37

Source: (9).

Table 17. Costs of a traveler (cable-tow) system 100 acres, six applications of 1 inch each, 1981

System	Investment costs	Annual costs
	Dollars	
Well, 10"; 400' (20 years, S.L. depreciation)	5,500	275.00
Pump, includes gearhead (600 gpm, 350 ft. TDH) (15 years, S.L. depreciation)	7,000	466.67
Power unit, 75 hp (12 years, S.L. depreciation)	7,000	583.33
Traveler unit, reel and hose (10 years, S.L. depreciation)	11,500	1,150.00
Underground pipe; 6"; 2400' (20 years, S.L. depreciation)	8,750	437.50
Diesel fuel, 4.4 gal./hr., 600 hrs. pumping time, fuel @ $1.20/gal.		3,168.00
Oil, 72 gal. @ $6/gal.		432.00
Repairs, 6 hrs. @ $15/hr.		90.00
Labor, 166 hrs. @ $3.50/hr.		581.00
Interest on investment, well, pump, power unit, traveler unit, and pipe, @ 10 percent		1,987.50
Taxes and insurance charged @ 0.5 percent of investment		198.75
Total costs	39,750	9,369.75
Annual operating cost/acre		42.71
Annual fixed costs/acre		50.99
Total annual costs/acre		93.70
Cost per acre-inch		15.62

Source: (9).

Table 18. Costs of a traveler (hard hose) system 100 acres, six applications of 1 inch each, 1981

System	Investment costs	Annual costs
Well, 10"; 400' (20 years, S.L. depreciation)	5,500	275.00
Pump, includes gearhead (600 gpm, 415 ft. TDH) (15 years, S.L. depreciation)	7,500	500.00
Power unit, 90 hp (12 years, S.L. depreciation)	7,750	645.83
Hard hose traveler unit (comp.) (10 years, S.L. depreciation)	23,500	2,350.00
Underground pipe; 6" PVC, 1200' (20 years, S.L. depreciation)	4,368	218.40
Diesel fuel, 5.2 gal./hr., 600 hrs. pumping time, fuel @ $1.20/gal.		3,744.00
Repairs, 6 hrs. @ $15/hr.		90.00
Labor, 60 hrs. @ $3.50/hr.		210.00
Interest on investment, well, pump, power unit, hard hose unit, pipe @ 10 percent		2,430.90
Taxes and insurance charged @ 0.5 percent of investment		234.09
Total costs	48,618	10,697.32
Annual operating cost/acre		40.44
Annual fixed costs/acre		66.54
Total annual costs/acre		106.98
Cost per acre-inch		17.83

Source: (9).

Table 19. Sprinkler irrigation system cost estimates for citrus production, Florida, 1983

Type of system	Initial costs	Fixed costs	Operating costs	Total costs 1/	
	Dollars per acre				Dollars per acre-inch
Under-tree spray jet 2/ Type 1	632	136.21	22.94	159.15	22.74
Under-tree spray jet 2/ Type 2	950	171.14	20.05	191.19	27.31
Traveling gun cable tow	655	117.97	105.63	223.60	24.84
Permanent 2/ overhead	1,192	171.17	38.95	210.12	23.35

Note: Cost analyses were based on a typical system size for irrigating 60 acres.

1/ Actual contract costs for complete systems. Based on water applications of 7 inches per year for trickle and 9 inches per year for traveling gun and permanent overhead systems.

2/ Designed to irrigate entire acreage simultaneously for cold protection and irrigation.

Source: (8).

The cost and return estimates for citrus are based on field surveys conducted by Muraro (12) of selected growers, statements by input suppliers, and from discussions with experts at the Agricultural Research and Education Center in Lake Alfred area. The budgets developed are for healthy, mature, rough lemon-rooted orange groves in the ridge areas of central Florida. The generation of cost and return data are designed to be applicable to any grove situation having good management and cultural practices. Other important factors considered are as follows: (1) it is a 25-year-old irrigated grove, (2) the plant type is round orange on rough lemon rootstock, (3) tree loss is 2 percent annually, (4) trees are pulled and replaced when production falls below 50 percent of the expected yield, (5) production is for processing only, and (6) trees are spaced at 70 per acre.

The net returns per acre for citrus varied from $752 in 1981-82 to $1,591 in 1982-83, as the market price and yields changed (table 21). Costs of producing citrus varied from $523 in 1979-80 to $647 in 1982-83. When the winter freeze occurred, the citrus yields dropped considerably. Especially note the reduction in citrus yields in 1981-82.

Table 20. Net returns per acre with center pivot irrigation for selected crops, Florida, 1982 1/

Crop type	Yield: Without irrigation	Yield: With irrigation	Yield: Change	Price per unit	Value added due to irrigation	Average irrigation cost	Change in net return
	Bushels			Dollars			
Corn	54	90	36	2.45	88.20	70.95	17.25
Soybeans	25	28	3	5.45	16.35	70.95	-54.60
	Cwt						
Potatoes	169	218	49	13.80	676.20	70.95	605.25

1/ Average irrigation applications vary with crop and local rainfall. A uniform application of 6 inches of irrigation water was assumed for the analysis.

Also, these data do not reflect costs incurred during freezes. Paying crew to stand by the heaters on the cold nights in one average season costs approximately $25 per acre. The cost of setting up and removing heaters and the amount of fuel used during the freeze also increases the costs resulting from cold weather.

For white seedless grapefruit grown in the Indian River area, the net return varied between a low of $242 in 1982-83 to a high of $869 in the year before (table 22). For the period 1979-84, the average net return per acre was $589. The main cultural practices, including plant density, are similar to orange crops grown in central Florida.

Table 21. Estimated annual per acre costs and returns for mature, round orange groves, produced for processing, central Florida, 1979-84

Year	Price per box	Yield per acre	Gross revenue	Total specified cost	Net returns per acre
	Dollars	Boxes	Dollars		
1979-80	3.90	404	1,575.60	523.39	1,052.21
1980-81	4.54	2/ 323	1,466.42	572.16	894.26
1981-82	4.15	2/ 323	1,340.45	588.27	752.18
1982-83	5.54	404	2,238.16	647.09	1,591.07
1983-84	1/ 6.25	323	2,018.75	646.87	1,371.88
Average for 5 years	4.88	355	1,732.40	3/ 595.56	1,136.84

1/ Estimated price.
2/ Yield reduced due to January or December freeze during 1981-1982 and 1983.
3/ Fixed costs such as taxes, debt payment, and insurance are not included.

Table 22. Estimated annual per acre costs and returns for a mature, white seedless grapefruit for fresh fruit packing, Indian River area, 1979-84

Year	Price per box	Yield per acre	Gross revenue	Total specified cost	Net returns per acre
	Dollars	Boxes	Dollars		
1979-80	3.35	375	1,256.25	486.26	769.99
1980-81	3.88	375	1,455.00	587.07	868.93
1981-82	2.51	2/ 323	848.38	601.36	247.02
1982-83	2.26	375	847.50	606.00	241.50
1983-84	1/ 3.98	375	1,492.50	665.02	827.48
Average for 5 years	3.20	368	1,170.60	3/ 588.94	588.66

1/ Estimated price.
2/ Yield reduced due to January 1982 freeze.
3/ Fixed costs such as taxes, debt service, and insurance are not included.

Selected Irrigated Vegetable Operations

The highest net returns in 1982-83 for any specific vegetable type are for tomatoes (20). For example, tomatoes grown in Dade County produced a net return of $2,449 per acre, while tomatoes grown in Manatee County averaged $2,062 per acre. Costs of producing tomatoes also varied for the counties, with the highest cost of production of $6,123 found in Dade County and $5,968 per acre in Manatee County.

Celery is another vegetable crop producing high returns per acre during 1982-83. This crop produced a net return of $1,475 per acre in Lake County and a net return of $701 per acre in the Everglades area, especially in Palm Beach County. Most of the difference in net returns between these two areas can be attributed to higher cost of production in the Everglades area. The cost of production of celery varied from $3,602 in Lake County to $4,482 per acre in Palm Beach County.

Leaf crops and squash were other important vegetable crops producing relatively high net returns per acre. Leaf crops grown in Lake County netted a return of $766, whereas squash grown in Palm Beach and Broward counties gave a net return of $579 per acre.

Potatoes produced in Dade County showed a loss of $484 per acre, while the potatoes grown in Putnam County in the northeast gave a net return of $293 per acre. Watermelon crops are grown especially in Collier, Hendry, and Lee counties and generated modest net returns in the amount of $198 per acre.

Sugarcane Production

Sugarcane is grown mainly in counties south of Lake Okeechobee because cane is highly sensitive to low temperatures. This crop was produced on 355,000 acres in 1982-83 and accounted for $542 million of gross revenues to the local economy. A net return in 1982-83 of $211 per acre was expected on the well-managed muck soils (1). Muck soils are specially suitable for this crop, because of its waterholding qualities, while sandy soils are less suitable for this crop.

These net returns are for a hypothetical farm located 15 miles from the mill and include no extra costs for transportation of cane to the mill. In order to reflect economies of scale, we assumed a large-sized and well-managed farm. In the 1983-84 season, the cost of producing 1 acre of sugarcane amounted to $866. These costs and returns are for freshly planted sugarcane, whereas for ratoon cane the yield and returns are usually lower. Ratoon cane can be grown for 2 to 4 years depending upon the quality of the standing crop. The quality of ratoon crop gradually deteriorates with years, especially in the fourth year.

Demand for Irrigated Crops

The demand for most irrigated crops is increasing. The frozen concentrate industry has allowed Florida citrus producers to widen their market. Nearly 94 percent of the 1982-83 crop was processed as concentrated juice (table 23). Grapefruit was grown on 129,000 acres in 1982-83 season, contributing about $82 million in gross value. Half of this crop was sold as fresh fruit. Tangerine production in Florida has been declining steadily; most of this crop is usually sold as fresh fruit. Florida's sugarcane production has expanded significantly since 1960, when the United States ceased importing Cuban sugar. In the 1980's,

Table 23. Oranges: Acreage, yield, production, use, season average price, and value, Florida

Crop year	Bearing acreage	Yield per acre	Use of production: Total	Fresh	Processed	On-tree: Price per box	Value of production
	1,000 acres	Boxes	1,000 boxes (90 lbs. box)			Dollars	1,000 dollars
1963-64	388.0	141	54,900	11,939	42,961	4.24	243,935
1964-65	435.0	189	82,400	14,598	67,243	2.43	200,276
1965-66	472.0	203	95,900	15,382	80,518	1.62	155,625
1966-67	522.0	267	139,500	17,876	121,624	.94	130,526
1967-68	557.6	180	100,500	17,096	83,404	2.07	207,432
1968-69	595.6	218	129,700	13,304	116,396	1.68	218,660
1969-70	636.1	216	137,700	13,263	124,437	1.14	156,876
1970-71	660.5	215	142,300	13,962	128,338	1.46	208,146
1971-72	624.2	219	137,000	11,233	125,767	2.04	280,317
1972-73	619.6	274	169,700	12,223	157,477	1.56	265,361
1973-74	614.6	270	165,800	11,090	154,710	1.47	244,691
1974-75	610.4	284	173,300	13,393	159,907	1.62	280,350
1975-76	596.4	304	181,200	11,730	169,470	1.77	321,449
1976-77	594.3	314	186,800	8,878	177,922	2.17	405,982
1977-78	579.0	290	167,800	9,966	157,834	4.14	693,677
1978-79	571.5	287	164,000	11,701	152,299	4.66	764,961
1979-80	576.6	358	206,700	10,990	195,710	3.72	768,877
1980-81	573.4	301	172,400	8,276	164,124	4.04	697,231
1981-82	560.2	225	125,800	7,620	118,180	4.28	538,686
1982-83	536.8	260	139,500	10,295	129,205	5.25	732,473

Note: The yields of citrus shown are lower than those given in table 21, because these yields are averages for both irrigated and nonirrigated citrus.

Source: (5).

Florida became the largest U.S. cane producer, accounting for 43 percent of the production in 1982. With the increase in production of sugarcane, irrigated acreage of this crop has also expanded as it has a high water requirement.

Florida alone accounted for 13.6 percent of the U.S. area harvested for vegetables and generated about 19.6 percent of the U.S. total value of these crops. The acreage of citrus and fresh vegetables grown in Florida has increased since 1954 and thus the probability for irrigation development is high, especially for citrus and vegetables.

POTENTIAL FOR IRRIGATION IN FLORIDA

According to the 1982 Census of Agriculture, 2.64 million acres of cropland were harvested in Florida, including approximately 1.6 million acres of irrigated cropland. Citrus, sugarcane, and vegetables have a national market, and any market expansion will increase the extent of irrigated cropland in Florida. Climatic conditions, along with large quantities of underground water resources in major producing areas, indicate further growth in irrigated land use.

The number of irrigated acres declined in Florida between the census years of 1978 and 1982. Close examination of the census data indicated that the decline occurred in irrigated pasture because 1982 rainfall was adequate during the early spring when pastures are typically irrigated. There were no indications that a major change had occurred in the irrigated sector and in longrun trends in irrigation.

Irrigation in Florida is expected to follow long-term trends during the next decade and reach and maintain a level of approximately 2.5 million irrigated acres of cropland and pasture. This assumes that the State will keep its market shares of citrus, sugarcane, vegetables, and specialty crops and that the national demand for these crops will keep pace with population and income changes.

Florida is the principal U.S. supplier of fresh vegetables during late fall and spring. Western Mexico produces vegetables for the U.S. market primarily between January and March. Florida's share of the October to June vegetable market has climbed to 51 percent. At the same time, Mexico's share has climbed to 40 percent. Both regions have been gaining market shares at the expense of Texas and the Caribbean nations.

Irrigation development in Florida over the next decade will be influenced by several factors which will influence both the number of acres and location of irrigation:

1. Irrigation will be used to a greater extent for secondary production purposes such as reducing freeze damage, crop cooling to delay early budding or blooming, application of chemical or chemigation, and land disposal of liquid livestock waste.

2. Irrigation may be expanded to remain competitive in specialty crops. Yield responses to irrigation in Florida are high in citrus (35-50 percent), corn (200 percent), and potatoes (25 percent). Irrigation is needed for vegetables produced during October to June when rainfall is below crop requirements.

3. Citrus suffered severe freeze damage in recent years which may trigger the relocation of citrus production. Production of citrus may shift further south where temperatures do not fall below 28°F as producers replace damaged growing stocks. Frequent water applications are required on the sandy soils to maintain product quality and output levels.

4. Irrigation will expand to meet the increase in national demand associated with population and income growth and Florida's share of specialty crop acreage will increase, as it has been increasing in the past 28 years.

5. Florida's production is concentrated in high-valued crops that produce high per-acre net returns. Tomatoes produce $2,000/acre net returns. Between $1,000-$2,000/acre net returns are earned for orange and celery crops. Grapefruit, vegetables, and potatoes have net returns between $500-$1,000/acre.

6. Florida is a water-rich State with adequate supplies of agricultural labor. Both irrigation and low-cost labor will help in remaining competitive and maintaining market shares.

7. In the long run, urban expansion will likely replace irrigated agriculture in urban areas as land is idled and residential and business development takes place. There is adequate land area to provide for both agriculture and urban expansion in the intermediate run.

The factors affecting irrigation in Florida are conducive to continued growth in the number of acres irrigated during the next decade. The expansion in demand for the major crops grown in the State will maintain the profitability of producing these crops and will likely lead to further expansion of irrigated cropland.

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Appendix 1

Total water withdrawn from different sources in Florida for all uses, by counties, 1980

Counties	Public supply	Rural fresh	Industrial self supplied fresh	Industrial self supplied saline	Irrigation fresh	Thermoelectric power generation fresh	Thermoelectric power generation saline	Total fresh	Total saline	Total all water
					Million gallons per day					
Alachua	18.18	8.52	1.63	--	19.23	1.44	--	49.00	--	49.00
Baker	.60	2.56	.30	--	1.82	--	--	5.28	--	5.28
Bay	39.50	1.59	1.48	--	.64	--	403.50	43.21	403.50	446.71
Bradford	1.05	2.91	4.77	--	.06	.02	--	8.81	--	8.81
Bevard	28.77	4.70	.24	--	166.76	.25	1,409.50	199.72	1,409.50	1,609.22
Broward	184.39	6.33	1.19	--	43.59	.16	1,103.0	235.66	1,103.00	1,338.66
Calhoun	.33	.75	.72	--	1.66	--	--	3.46	--	3.46
Charlotte	4.93	1.24	.00	--	24.90	--	--	31.16	--	31.16
Citrus	.91	5.84	.55	--	4.17	.57	1,897.0	12.04	1,897.00	1,909.04
Clay	1.83	9.94	3.20	--	1.10	--	--	16.07	--	16.07
Collier	19.30	2.56	2.33	--	86.95	--	--	111.14	--	111.14
Columbia	2.01	4.81	.27	--	.93	--	--	8.02	--	8.02
Dade	306.46	18.65	19.73	--	89.58	1.00	2,200.00	435.32	2,200.00	2,635.32
De Soto	.71	2.15	.53	--	34.34	--	--	37.73	--	37.73
Dixie	.55	.51	.43	--	.29	--	--	1.78	--	1.78
Duval	59.56	21.65	64.29	--	.37	4.93	1,225.00	150.80	1,225.00	1,375.80
Escambia	30.46	4.15	54.98	.24	2.30	335.60	--	427.49	.24	427.73
Flagler	.77	.56	--	--	4.07	--	--	5.40	--	5.40
Franklin	1.00	.29	.01	--	--	--	--	1.30	--	1.30
Gadsden	2.24	3.12	1.84	--	6.29	--	--	13.49	--	13.49
Gilbert	.36	1.08	.06	--	1.20	--	--	2.70	--	2.70
Glades	.21	1.28	--	--	124.22	--	--	125.71	--	125.71
Gulf	.97	.57	33.94	13.00	--	--	--	35.48	13.00	48.48
Hamilton	.68	.80	69.94	--	.70	--	--	72.12	--	72.12
Hardee	1.27	2.58	.79	--	38.91	--	--	43.55	--	43.55

Continued --

Appendix 1

Total water withdrawn from different sources in Florida for all uses, by counties, 1980

Counties	Public supply	Rural fresh	Industrial self supplied fresh	Industrial self supplied saline	Irrigation fresh	Thermoelectric power generation fresh	Thermoelectric power generation saline	Total fresh	Total saline	Total all water
	Million gallons per day									
Hendry	2.00	2.50	.23	--	243.53	--	--	248.26	--	248.26
Hernando	1.14	4.92	31.60	--	3.97	--	--	41.63	--	41.63
Highlands	4.95	6.30	.95	--	87.56	78.71	--	178.47	--	178.47
Hillsborough	84.70	10.22	26.77	38.39	72.88	2.77	2,180.30	197.34	2,218.69	2,416.03
Holmes	.64	1.84	.06	--	.26	--	--	2.80	--	2.80
Indian River	6.21	4.47	1.07	.83	278.28	4.30	54.60	294.33	55.43	349.76
Jackson	2.15	3.08	.84	--	11.46	118.00	--	135.53	--	135.53
Jefferson	.49	1.28	.05	--	.73	--	--	2.55	--	2.55
Lafayette	.12	1.38	--	--	1.07	--	--	2.57	--	2.57
Lake	11.39	6.46	11.18	--	72.12	--	--	101.15	--	101.15
Lee	29.84	6.31	4.09	--	46.42	487.42	--	574.22	--	574.22
Leon	17.20	3.61	11.26	--	2.35	4.20	--	38.62	--	38.62
Levy	1.10	2.20	.22	--	2.10	--	--	5.62	--	5.62
Liberty	.13	.30	.33	--	--	--	--	.76	--	.76
Madison	.96	1.53	.04	--	1.07	--	--	3.60	--	3.60
Manatee	20.86	5.38	.19	--	65.60	3.60	--	95.63		95.63
Marion	6.78	9.11	1.57	--	19.47	--	--	36.93	--	36.93
Martin	6.15	6.38	.12	--	138.93	40.30	--	191.88	--	191.88
Monroe	3.76	--	--	--	.49	.20	79.00	4.45	79.00	83.45
Nassau	2.77	7.12	59.18	2.00	.39	39.00	--	108.46	2.00	110.46
Okaloosa	12.94	3.97	4.62	--	.12	--	--	21.65	--	21.65
Okeechobee	1.55	7.35	.18	--	82.42	--	--	91.50	--	91.50
Orange	69.41	15.34	15.24	--	93.47	22.60	--	216.06	--	216.06
Osceola	4.19	5.52	.70	--	20.22	1.00	--	31.63	--	31.63
Palm Beach	123.81	11.82	2.67	3.02	614.23	.77	547.10	753.30	550.12	1,303.42

Continued --

Appendix 1

Total water withdrawn from different sources in Florida for all uses, by counties, 1980

Counties	Public supply	Rural fresh	Industrial self supplied fresh	Industrial self supplied saline	Irrigation fresh	Thermoelectric power generation fresh	Thermoelectric power generation saline	Total fresh	Total saline	Total all water
					Million gallons per day					
Pasco	11.92	7.71	15.83	--	20.07	.26	1,339.00	55.79	1,339.00	1,394.79
Pinellas	102.85	3.39	.89	--	9.21	.11	800.00	116.45	800.00	916.45
Polk	35.54	16.00	208.71	--	54.70	295.40	--	610.35	--	610.35
Putnam	2.86	5.30	40.23	--	36.30	.33	--	85.02	--	85.02
St. John	2.98	4.91	.01	--	29.55	--	--	37.45	--	37.45
St Lucie	9.69	3.92	2.05	--	231.28	1.40	586.60	248.34	586.60	834.94
Santa Rosa	5.83	.88	18.52	--	.81	--	--	26.04	--	26.04
Sarasota	19.54	1.64	.10	--	20.80	--	--	42.08	--	42.08
Seminole	13.98	13.13	3.80	--	24.68	--	--	55.59	--	55.59
Sumter	1.02	2.57	1.14	--	16.67	--	--	21.40	--	21.40
Suwannee	1.06	2.74	.70	--	8.40	172.81	--	185.71	--	185.71
Taylor	1.49	1.09	51.05	--	.03	--	--	53.66	--	53.66
Union	.57	.61	--	--	.12	--	--	1.30	--	1.30
Volusia	26.57	6.25	.33	--	23.32	154.65	15.20	211.12	15.20	226.32
Wakulla	.56	.74	.81	--	--	86.76	--	88.87	--	88.87
Walton	1.62	1.01	.74	--	9.18	--	--	12.55	--	12.55
Washington	.92	1.03	.04	--	--	--	--	1.99	--	1.99
Total	1,361.28	310.35	781.33	57.48	2,997.43	1,858.70	13,839.80	7,309.09	13,897.27	21,206.37
							Million acre-feet per year	8.19	15.57	23.76

-- = Data are not available.
(Amounts less than 5,000 gallons per day are not reported.)
Data Source: Department of Natural Resources and Bureau of Geology, Tallahassee, Florida, 1982.

Appendix 2

Citrus irrigation in Florida (demonstration project costs)

7 inches of irrigation application

Item	Investment cost	Annual costs
Well (8 inches, 700' deep)	Dollars	
Pump, power unit & pump house (10 year, S.L. depreciation)	20,724.88	2,072.49
Microjet* system, irrigate all		
at-1 set; pump (1140 gpm), above ground laterals and buried main lines (10 years, S.L. depreciation)	17,305.81	1,730.58
Energy; 115 hrs, @ 5.08 gal per hr = 584.2 gal @ $1.20/gal		701.04
Labor, @ 0.10/mhr/acre-in 280 ac. in** X .10 X $3.60		100.80
Interest on investment, @ 15/0		2582.30
Taxes and insurance @ 1/2% inv.		190.15
Total costs	38,030.69	7,647.36
Annual operating costs per acre		20.05
Annual fixed costs per acre		171.14
Total annual costs per acre		191.19

Source: (8).

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